

## THE MARINE FOSSILS FROM SANTA MARIA ISLAND: AN HISTORICAL OVERVIEW

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### ABSTRACT

In the Azores, Santa Maria is the only island with a sedimentary cover in a nine island volcanic system. This southeast most island of the archipelago has a rich fossil record, dated to the Late Miocene-Early Pliocene and to the Pleistocene. Palaeontological investigations on the island started in the late nineteenth century. Nevertheless, through the next 150 years, the number of publications and thus the attention given to the fossil record of Santa Maria shows considerable fluctuation over time. From the beginning, the Miocene-Pliocene outcrops, more numerous in the island, focused the attention of the scholars. Recently, however, the interest has shifted to the Pleistocene outcrops.

Data obtained from these outcrops has been used extensively in the interpretation and discussion of the Azorean geological genesis and evolution, particularly of Santa Maria, the oldest island of the archipelago. However, its role in the interpretation and discussion of the origin and subsequent evolution of insular marine communities has been meagre.

The checklists produced for Santa Maria's fossiliferous outcrops, account for a large spectrum of represented animal groups. Workers have focused their attention on the molluscs, being the group best represented in the fossil record. Data on other animal groups is still scarce, particularly in case of the Pleistocene outcrops. The fossiliferous beds of Santa Maria are far from being an exhausted matter and further research in the Island should be considered.

### INTRODUCTION

Santa Maria Island (Lat. 37° 23' N; Long. 24° 45' W) is located in the south-eastern most end of the Azores

Archipelago, in the North-eastern Atlantic. Like the remaining eight islands, it is of volcanic origin. However, except for the small islets of Formigas (about 30 km to the NE

of Santa Maria), Santa Maria is the only island where fossiliferous outcrops were detected.

In the 16<sup>th</sup> century, Gaspar Frutuoso (1983) described a quarry at Figueiral, where the extracted calcareous sandstones had “seafood shells glued on it”. He also stated that Santa Maria “limestone” was unique in the archipelago, but of lesser quality for construction purposes, than imported limestone from the Portuguese mainland. Though named as such by local people, the “limestones” of Santa Maria are mostly well lithified, lithic sandstones and calcarenites. Pure calcareous units, in contrast, are rare and poorly developed, being restricted to tin beds of bioclastic rud- and wackestones in most of the outcrops. Gaspar Frutuoso’s iterations, illustrate the importance of these sedimentary units for the inhabitants of these volcanic islands otherwise bare of suitable building stone.

The first scientific reports on the geology of this island date back to the 19<sup>th</sup> century, with the studies by Bronn (1860), Hartung (1860) and Morelet (1860). The former two authors produced the first thorough geological studies on the island, with extensive descriptions of its geomorphology. These investigations, together with the ones of Reiss (1862), Hartung (1864) and Mayer (1864), provided the framework for the palaeontological work in Santa Maria during the 20<sup>th</sup> century. By the end of the 19<sup>th</sup> century, Cotter (1892) published an update to the previously published faunal lists.

With the turn of the 20<sup>th</sup> century the palaeontological interest in Santa Maria Island decreased to almost total oblivion, with the exceptions of Friedlander (1929), and the reviews of Agostinho (1937a, 1937b). These works focussing on the geological origin of Santa Maria and its volcanic structures, but yielding no new palaeontological data.

The interest on the fossil outcrops of Santa Maria rose again in the second half of the 20<sup>th</sup> century, expressed by a series of studies published in rapid succession: Berthois (1950, 1951, 1953a, 1953b, 1953c), Ferreira (1952, 1955), Krejci-Graf *et al.* (1958) and reproductions of the 19<sup>th</sup> century studies by Teixeira (1950). This enhanced attention persisted through the next decades, with the prolific publication of palaeontological reports. During this time, Zbyszewski *et al.* (1961) produced a geological map with several explanatory notes, where the fossil contents of the island outcrops were again discussed (Ferreira, 1961a; Zbyszewski & Ferreira, 1961, 1962a, 1962b). After these productive decades, the scientific reports on the fossils of Santa Maria Island became scarce again. Some exceptions are the revisions on the sedimentary rocks of the Macaronesian islands by Mitchell-Thomé (1974, 1976, 1981), and the papers of García-Talavera (1990) and Callapez & Soares (2000) on the Pleistocene outcrops of Prainha and Lagoinhas.

In 2002, Santa Maria’s outcrops were revisited by a scientific expedition organized by elements of the

Marine PalaeoBiogeographic Working Group (MPB) and of the Department of Biology of the University of the Azores. The main objectives were aimed at understanding the palaeoecology and palaeobiogeography of the Pleistocene and Miocene-Pliocene outcrops, as well as towards the legal protection of the geological legacy of Santa Maria Island. As a result, a checklist of the Pleistocene molluscs of Lagoinhas and Prainha was produced (Ávila *et al.*, 2002), as well as a technical report for the protection of the outcrops of Pedreira do Campo and Figueiral (Cachão *et al.*, 2003). The recently formed MPB intends to continue on further research activities, e.g. the 2<sup>nd</sup> International Congress “Atlantic Islands Neogene” (AINIC) that will be held at Ponta Delgada Azores, in September 2008, and the international workshops “Palaeontology in Atlantic Islands” (this volume), all aiming at a better understanding of Santa Maria’s palaeontology and stratigraphy.

### **The Geological History of Santa Maria Island**

Santa Maria is a relatively small island, with 97 km<sup>2</sup> and a maximum length of 16.8 km (França *et al.*, 2003). The island can be divided in two distinct physiographic regions: the western part, relatively flat with erosional surfaces at different altitudes, and a more irregular eastern part (Abdel-Monem *et al.* 1975). These regions are separated by a central mountain chain extending NNW-SSE between Lagoinhas and Glória, coinciding

with the highest point of the island at Pico Alto (590 m) (Zbyszewski *et al.*, 1961). The coast of Santa Maria is characterized by steep cliffs, from 30 m (Ponta do Marvão) to 342 m (Rocha Alta), in places interrupted by small bays with sandy beaches (Praia, Maia, São Lourenço and Anjos) (Serralheiro, 2003).

Hartung (1860) and Reiss (1862) extensively described the geological landscape of Santa Maria, and located most of the fossil outcrops that we know today. Almost one hundred years later, Zbyszewski *et al.* (1961) published a geological map with several explanatory notes, where the fossil contents of the island outcrops were again discussed. A new, more detailed geological map was produced by Serralheiro *et al.* (1987) focusing on the volcanic structures of Santa Maria. Recently, an update to this map was published (Serralheiro, 2003).

In his review, Mitchell-Thomé (1976) postulated the age of the Azorean archipelago as Late Miocene or Early Pliocene. Abdel-Monem *et al.* (1975) published radiometric (K-Ar) age estimates for the volcanic rocks in the eastern Azores group. They dated the basaltic series exposed below the fossiliferous sediments (“coquina zone”) of Santa Maria to 6-8 Ma B.P. A maximum estimate of 8.12 Ma was obtained for the area below the airport runway about 70 m above the present sea level. Although, the exact age of Santa Maria Island is still a matter of debate (e.g., Serralheiro & Madeira, 1990, Serralheiro, 2003), the data presented by these authors show

that it is the oldest island in the Azorean archipelago, confirming the assumptions made by Agostinho (1937b), who considered that the differential degree of deterioration of the volcanic rocks was possibly testifying different periods of volcanic activity. Zbyszewski *et al.* (1961) assumed three general phases in the history of the island formation: pre-“Vindobonian”, “Vindobonian” (which includes the deposition of the Santa Maria sedimentary units) and post-“Vindobonian” (the “Vindobonian” stage is an outdated stratigraphical term, corresponding to the Middle Miocene today). The discussion on origin and evolution of the Santa Maria continued throughout the late 20<sup>th</sup> century (e.g., Madeira, 1986; Storetvedt *et al.*, 1989; Serralheiro & Madeira, 1990). In the following paragraphs the history of the geological evolution of Santa Maria Island is given, based on the review of Serralheiro (2003).

The Cabrestantes Formation in the west of Santa Maria Island was considered by Serralheiro (2003) to be the oldest formation in the island. Standing today at an altitude of no more than 33 m, this structure was formed by initial submarine volcanic activity. After the initial period of volcanic activity, the sea level experienced a regression, dropping below today’s level. This period was characterized by the erosion and weathering of the exposed island. However, Serralheiro (2003) states that with today’s data it is not possible to understand the magnitude or duration of the regression and the exten-

sion of the eroded materials. Afterwards, volcanic activity restarted with increasing intensity and distribution, and contrary to the previous event, it was of subaerial nature, leading ultimately to the formation of the Anjos Complex during the Tortonian stage (11.61-7.25 Ma). The Anjos Complex is responsible for increasing Santa Maria about 3 km to the north, modelling the island to a somewhat square shape, with round corners, very different from today. Serralheiro (2003) adds that the Lagoinhas islets are a testimony to the island growth, subsequently and progressively destroyed by sea erosion.

The eruptive period that lead to the development of Anjos Complex, was followed by a relatively calm phase, characterised by the erosion and weathering of the old volcanic landscape. Afterwards, the island experienced a transgression, during the transition from the Messinian (Late Miocene) to the Pliocene (~5 Ma), when sea level reached at least 180 m of altitude (Serralheiro, 2003). On the south side the submarine eruptions were intense, contrasting with the highly erosive environment in the north, which placed the shoreline back to the area near the Lagoinhas islets. The Touril Complex was formed during this long period, including its thick sedimentary beds.

Volcanic activity restarted with great intensity during the formation of Facho-Pico Alto Complex (Lower Pliocene). This period was characterized by the explosive submarine volcanic activity, which raised the vol-

canic cones of the Pico do Facho. Volcanic activity continued throughout this period, spreading its materials from the Airport in the west of Santa Maria, to the southeast in Baixa do Sul and to the north in Ponta do Norte, increasing the size of the island to its present dimensions. Later volcanic activity shifted to the east-southeast part of the island and changed to the subaerial type due to a marine regression. The eruptions were then interrupted by a relatively calm phase of erosion.

During the late Pliocene, volcanic activity restarted giving rise to the Feteiras Complex, with great explosive manifestations spreading throughout the island. After this eruptive phase, another transgression occurred by the end of the Pliocene. The sea level reached the altitude of 200 m, forming the old beach deposits and extensive wave cut platforms, especially visible in the west part of the island up to 120 m. Since the Quaternary, Santa Maria has risen relatively to sea level progressively, but not continuously, until the today's position (Serralheiro & Madeira, 1990). Presently, Santa Maria shows no signs of recent volcanic activity or any kind of secondary volcanism (Agostinho, 1937b).

### **The sedimentary stratigraphy of Santa Maria**

Mayer (1864) assigned the fossils from the Miocene outcrops of Santa Maria Island to the "Mayencian" and "Helvetian" stages, today corresponding to the Middle and Lower

Miocene, respectively. One hundred years later, Zbyszewski & Ferreira (1962b), placed them in the "Vinbodonian" (an outdated term for the Middle Miocene). Based on the foraminiferal data of Colom (1958 *in* Krejci-Graf *et al.*, 1958) and new radiometric dates, Abdel-Monem *et al.* (1975) rejected these age assignments and proposed a younger, Late Miocene to Early Pliocene age (around 5.3 Ma). Aside from the sub-recent sedimentary deposits, the geological map of Serralheiro *et al.* (1987) shows two lithostratigraphic units composed of sedimentary rocks of two ages: Late Miocene and Pliocene. The former are mainly distributed on the west part of the island, and the latter on the central and east areas, at altitudes that can reach about 400 m (e.g., in areas near Pico Alto). In 2003, Serralheiro reviews the data given by the earlier workers, including the ones mentioned above by Zbyszewski & Ferreira (1962b) and by Colom (1958 *in* Krejci-Graf *et al.*, 1958), and agrees with the latter, assigning the Miocene deposits to the Messinian (Late Miocene) or possibly early Pliocene.

In general terms, the sedimentary deposits in Santa Maria consist of horizontal layers intercalated in volcanic material, and are represented by limestones, breccias, sandstones, conglomerates and subaerial deposits (Agostinho, 1937b; Ferreira, 1955; Mitchell-Thomé, 1976). Agostinho (1937b) claimed that the maximum altitude reached by the outcrops was no higher than 130 m

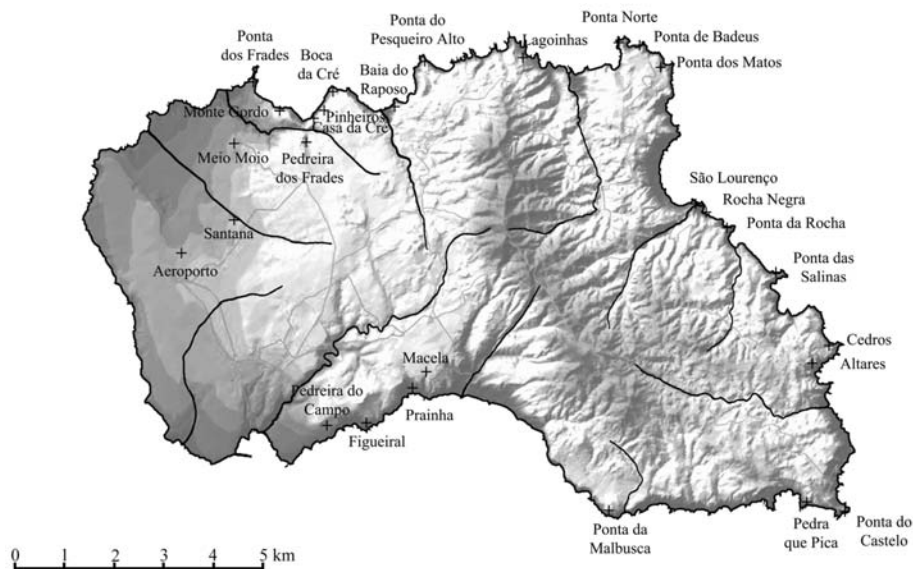


FIGURE 1. Map with the fossiliferous outcrops of Santa Maria Island (adapted from Ferreira, 1955, 1961a).

above the sea level at Pico do Facho. Such was contradicted by Mitchell-Thomé (1976), who based on the observation of the geological map by Zbyszewski *et al.* (1961), stated that sedimentary rocks occurred as high as 400 m in Pico Alto. Berthois (1953c) in his extensive description of the lithology of the calcareous rocks of Santa Maria, believed that the present elevations of the limestone depositions are partially original.

In the following paragraphs we provide a description of the fossiliferous outcrops (see Fig. 1). The naming of the outcrops is based on the map by Serralheiro *et al.* (1987) and, with few exceptions, is consistent with the historical works.

### The outcrops of Santa Maria Island

In the west part of Santa Maria Island, the geological map of Serralheiro *et al.* (1987) shows the presence of Upper Miocene and Quaternary deposits on the area of the Airport and Santana. Though, these Quaternary beaches at about 90 m of altitude can be easily correlated with the Airport deposits referred to in the bibliography (e.g., Berthois, 1950; Zbyszewski & Ferreira, 1962a), the same cannot be stated for the Miocene limestone outcrops. Ferreira (1961b) mentioned an old quarry of relatively small extension in the area called Antigas Crés, which by its position appears to be correlated to the Acácias (or Assumada, as was called by the author) and Meio Moio



outcrops, located to the North of the island, near Baía da Cré.

Baía da Cré, in the north of Santa Maria Island, to the east of Baía dos Anjos, was noticed by the first investigators for its rich fossil content, particularly the outcrops located in the east part of the bay - Boca da Cré and Pinheiros (Hartung, 1860; Reiss, 1862; Mayer, 1864). Aside from those two sites, additional outcrops were studied by Zbyszewski & Ferreira (1962a, b): Meio Moio, Acácias, Pedreira dos Frades, Monte Gordo, Ponta dos Frades and Casa da Cré or Escarpa da Cré. In general, these sedimentary deposits do not reach higher than 60 m above present sea level (Ferreira, 1961a), with maximum of ~120 m at Casa da Cré (our data), and about 100 m at Monte Gordo or Meio Moio (Teixeira, 1950).

The Miocene sedimentary depositions continue through the north coast of Santa Maria, to the east of Baía da Cré. In Baía do Raposo, the documented outcrops are located in the small valley formed by the Ribeira do Engenho, and in the north-east extreme of the bay, Ponta do Pesqueiro Alto, referred also as Tamuscal or Tamugal (Reiss, 1862; Ferreira, 1961a). The geology of this area is discussed in greater detail by Zbyszewski & Ferreira (1962a).

In the north extreme of the island, three Miocene localities have been documented: Ponta do Norte, Ponta de Badeus and Ponta dos Matos. These deposits are described to some extent by Reiss (1862), Ferreira (1961a), Zbyszewski *et al.* (1961) and Zbyszewski & Ferreira (1962a). The

faunal diversity of Ponta dos Matos is relatively low (Mayer, 1864; Ferreira, 1955), yet that outcrop yielded taxa not encountered anywhere else (e.g. the brachiopod *Terebratulina retusa* [= *T. caputserpentis* of former authors]). From the first two localities, Zbyszewski *et al.* (1961) described 3 layers of fossiliferous brownish limestone, no thicker than 2 m, intercalated with basaltic lavas.

Following the coastline to the south, a number of Miocene deposits are documented: São Lourenço (on the southeast end of the bay), Rocha Negra and Ponta da Rocha (see Ferreira, 1961a). The last outcrop was referred also as by the name of Pontinha or Ponta do Papagaio (Hartung, 1860, 1864; Krejci-Graf *et al.*, 1958; Zbyszewski *et al.*, 1961).

The sedimentary rocks in the area of Ponta das Salinas, known traditionally by the name of Feteirinha or Feteirinhas (Hartung, 1860; Reiss, 1862; Mayer, 1864), lie about 30 m above present sea level (Agostinho, 1937b) and are exposed in disused quarries described by Ferreira (1961a). Additional Miocene outcrops on the east coast of Santa Maria are Cedros and Altares (Zbyszewski & Ferreira, 1962a), which lie roughly about 20 m above the sea level. Ferreira (1961a) in his survey of economical interesting limestone deposits addressed these two as unsuitable. The deposits of Cedros were too small and Altares outcrop was at that time an almost exhausted quarry of extremely difficult access. To the south, sedimentary units only appear again in the locality of Maia,

mainly to the south-eastern end of the island, at Ponta do Castelo. This area, particularly to the west, in the direction of Ponta da Malbusca, is characterised by thin beds of fossiliferous marine sandstone (and subordinate limestone) intercalated between volcanic layers (basalt flows, pillow lavae and volcanoclastics) (Serralheiro *et al.*, 1987). The Ponta do Castelo section was described by Zbyszewski *et al.* (1961) and Zbyszewski & Ferreira (1962a). In the area near Baixa do Sul, between Ponta do Castelo and Rocha Alta, Serralheiro (2003) mentioned for the first time a fossil outcrop about 3 m thickness which he called "Pedraque-Pica".

Along the south coast of Santa Maria, near Piedade locality in an area of steep cliffs, there is an old limestone quarry (Ferreira, 1961a), earlier referred to as Forno da Cré (Hartung, 1860; Reiss, 1862; Mayer, 1864; Cotter, 1892, 1953). Other designations were used too: Agostinho (1937b) called it "Cré", Ferreira (1961a) used the name "Furna da Cré" and Zbyszewski & Ferreira (1962a, 1962b) called it "Boca da Cré", a designation used as well for the north locality of Baía da Cré. Zbyszewski & Ferreira (1962a, 1962b) argued that the use of "Bocca do Cré" by Hartung (1860) to designate the north outcrop was not correct, for the local people use this name for the south locality near Piedade. In this work we prefer to use the name given in the map of Serralheiro *et al.* (1987), Ponta da Malbusca, to prevent confusions. We restrict the use Boca da Cré

to the north outcrop, as done by Hartung (1860) and subsequent investigators. Ferreira (1961a) positioned the Malbusca outcrop close to the sea level. However, Zbyszewski *et al.* (1961) and Zbyszewski & Ferreira (1962a) described a 180 m high cliff containing two sedimentary deposits of 3.5, respectively 12 m thickness, framed by volcanic lavas. According to their data, these layers lie roughly 60 m above the present sea level, which agrees with the altitude given by Agostinho (1937b) for this outcrop and our own field observations.

The area south of Pico do Facho, east to Vila do Porto, is rich in sedimentary strata (Serralheiro *et al.*, 1987). In this area the Miocene outcrops reach their highest elevations (between 120 and 130 m above present sea level; Agostinho, 1937b; Ferreira, 1962). Nowadays, two outcrops are recognized, Pedreira do Campo and Figueiral, all included in an area classified as a Natural Monument (Cachão *et al.*, 2003). Figueiral is well known since the first naturalists (Hartung, 1860; Reiss, 1862; Mayer, 1864), for it is the place of one of the oldest "limestone" quarries in Santa Maria and has been mentioned commonly (Ferreira, 1952, 1955, 1961a; Zbyszewski & Ferreira, 1962a; Zbyszewski *et al.*, 1961). Pedreira do Campo (also known as Pedreira do Facho) is situated near Figueiral, to the south of Pico do Facho. Although discovered by García-Talavera (*pers. com.*) in 1997, it attracted the attention of scientists and the local community only



after the first international expedition "*Palaeontology in Atlantic Islands*", in 2002. A technical report was produced for the local government, in order to protect this outcrop and Figueiral (see Cachão *et al.*, 2003), and to stop stone extraction from the Pedreira do Campo area.

In the area of Prainha, at an altitude between 100 to 110 m above the present sea level, Berthois (1953c) described Miocene sediments. The fossils contained are poorly preserved, due to leaching and recrystallization (aragonitic molluscs being preserved in form of moulds only). In this work we call this outcrop by Macela, based on the name given to the hills that surround the west part of this bay, thus differentiating it from the Pleistocene deposits of Prainha.

Although the Miocene outcrops were given more attention since the beginning of the palaeontological work on Santa Maria, the Pleistocene deposits of Praia Formosa and Prainha attracted even more attention (Mayer, 1864; Berthois, 1950, 1951, 1953c; Ferreira, 1961a; Zbyszewski & Ferreira, 1961, 1962a; Zbyszewski *et al.*, 1961; García-Talavera, 1990; Ávila *et al.*, 2001; Amen, 2002; Ávila *et al.*, 2002; Amen *et al.*, 2005; Ávila, 2005). Located to the southeast of Pico do Facho, the exposed Pleistocene deposits lie 2 to 3 m above present sea level (García-Talavera, 1990), and extend from Prainha until the far west end of Praia Formosa (Zbyszewski & Ferreira, 1961). In the literature two names are used to designate these

outcrops: Praia and Prainha. The sedimentary succession of Prainha was studied thoroughly by the authors listed above. It is characterized by a basal conglomerate with algal-limestone concretions, followed by 0.8 to 3.0 m of fossiliferous sands (interpreted as beaches deposits) rich in micro-molluscs (Ávila *et al.*, 2002; Ávila, 2005). Zbyszewski & Ferreira (1961) and García-Talavera (1990) assigned the sediments of Prainha to the Tyrrhenian stage.

The area near the Ilhéu da Lagoinhas, to the west end of Baía do Tagarete, in the north of Santa Maria Island, is relatively rich in Pleistocene deposits. However, the first report on these depositions was made only in the turn of the millenium by Callapez & Soares (2000). These authors correlated this outcrop, known as Lagoinhas, to the Pleistocene outcrop of Prainha. Similar to the latter, the outcrop is located about 7 m above the present sea level and is characterized by a basal conglomerate, coralline red algae crusts (algal biostromes of up to 0.2 m thickness), followed by 0.7 m bioclastic cross-bedded sands rich in fossil molluscs (interpreted as beach deposits; Ávila *et al.*, 2002). Based on the malacofauna, Callapez & Soares (2000) assigned the Lagoinhas outcrop the Tyrrhenian stage, corroborating the dates for Prainha. Both outcrops were later studied by Ávila and co-workers (2001, 2002, and 2005), giving further details on their litho-stratigraphy and fossil content.

### **The fossils of Santa Maria Island: molluscs and other groups**

In the faunal lists produced through the years, the Molluscs are the best represented group from the outcrops of Santa Maria. Zbyszewski & Ferreira (1962b) in their work on the Miocene fossils reported a total of 188 animal species for the island: 32 foraminifers, 2 anthozoans, 4 echinoids, 2 annelids, 5 bryozoans, 1 brachiopod, 66 bivalves, 64 gastropods, 2 cirripeds, 1 decapod, 8 fishes and the undetermined remains of cetacean vertebras and ribs.

Berthois (1950) documented the presence of microfossils at Prainha (e.g. green algae, coccoliths and foraminifers), as well as the remains of the macrofauna (e.g. fish scales, fragments of echinoid spines and tests, holothurian ossicles, corals debris, bryozoans, brachiopods, gastropods and red algae). Aside from the molluscs, Callapez & Soares (2000) reported bryozoan, cirriped and echinoid fragments from Lagoinhas. The last addition to the Pleistocene malacofauna of Santa Maria Island was given by Ávila *et al.* (2002), summing 89 records, including 75 gastropods and 14 bivalves.

The particularly good fossil record of molluscs can be explained by a combination of initial abundance, taphonomic biases and selective investigations (most palaeontological studies on Santa Maria focused on molluscs).

For the macrofauna existing in the sedimentary outcrops of Santa Maria, the reviews on the Portuguese Miocene fishes and echinoids, respec-

tively by Zbyszewski & Almeida (1950) and Ferreira (1961b), are the only classical works on animal groups other than the molluscs. The number of works published on the fossil microfauna is likewise rather limited: Berthois (1950), Collom (*in* Krejci-Graf *et al.*, 1958) and Ferreira (1960). Calcareous red algae, particularly well developed in the Pleistocene outcrops of Prainha and Lagoinhas, were only recently a target group for the studies by Amen (2002) and Amen *et al.* (2005). In sum, the fossil record of Santa Maria Islands is without doubt an issue far from being exhausted. Additional attention should be given to groups of organisms other than molluscs in future studies.

### **The past Azorean communities and their biogeography**

Despite numerous faunal lists being available after almost 150 years of investigations the palaeoecological and palaeobiogeographical implications of these faunas remained poorly studied. Questions concerning the evolution of the Azorean fossil fauna and its relation to extant communities are largely un-answered.

Biogeographical studies on the archipelago, largely ignored palaeontological data (e.g., Boury-Esnault & Lopes, 1985; Prud'homme van Reine, 1988; Cornelius, 1992; Lopes *et al.*, 1993; Wirtz & Martins, 1993; Tittley & Neto, 1995; Santos *et al.*, 1995; Santos *et al.*, 1997; Ávila, 2000; Tittley & Neto, 2006). Only in the most recent studies, Pleistocene mollusc faunas

were included in an attempt to understand Santa Maria's palaeobiogeographical relationships (García-Talavera, 1990; Callapez & Soares, 2000; Ávila *et al.*, 2001; Ávila *et al.*, 2002; Ávila, 2005).

### **The Portuguese fossil collections**

Nowadays, there are five institutions on the Portuguese territory with palaeontological collections harbouring specimens from Santa Maria fossiliferous outcrops: the Museu Geológico (Geological Museum) (INETI) in Lisbon, the Museu de Zoologia - Museu de História Natural da Faculdade de Ciências e Tecnologia da Universidade de Coimbra (MZ/MHN-FCTUC) in Coimbra, the "Museu dos Montanheiros" in Angra do Heroísmo (Terceira Island, Azores), the Museu Carlos Machado/ História Natural (MCM(HN) in Ponta Delgada (São Miguel Island, Azores) and the Department of Biology of the University of the Azores (DBUA-F) in Ponta Delgada (São Miguel Island, Azores). In the Geological Museum (Lisbon) we could locate the specimens studied by Cotter and the material collected by Zbyszewski and co-workers. The University of Coimbra houses the material from Lagoinhas collected by Soares. In the University of the Azores it is deposited the most complete collection of Santa Maria fossils, as a result of several expeditions since 1998, organized by the members of the Marine PalaeoBiogeography Working Group (MPB).

### **CONCLUSIONS**

Palaeontological studies relating to Santa Maria Island depended primarily on few expeditions made in the last two centuries and on valuable donations made by private collectors. Several palaeontological works were produced during this time, especially about the fossil molluscs, but little is known on other animal groups present in the outcrops. This is also true for microfossils and nannofossils, despite their biostratigraphic value. During the 20<sup>th</sup> century, several workers targeted the numerous Upper Miocene-Lower Pliocene outcrops in their studies. This tendency changed by the end of the millennium, with the production of numerous papers on the Pleistocene strata, many of which aimed at the understanding of the biogeographical relationships of the archipelago throughout its history. Thus, although this recent attention on the Pleistocene outcrops is still far from being exhausted, a renewed look must be given to the Miocene-Pliocene outcrops. Mitchel-Thomé (1976) classified the palaeontological situation in Santa Maria Island, as "(...) a promising field", and it seems that it still holds.

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